From Milankovitch to El Niño: Using proxies and models to understand the dynamics of the climate system

Steven J. Phipps
ARC Centre of Excellence for Climate System Science
Climate Change Research Centre
University of New South Wales, Sydney, Australia

Asia Oceania Geosciences Society 10th Annual Meeting
24 June 2013
Introduction

Steven J. Phipps, ARC CoE for Climate System Science and Climate Change Research Centre, UNSW, Sydney, Australia

From Milankovitch to El Niño: Using proxies and models to understand the dynamics of the climate system
The “handshake” question

How do we integrate proxy data and climate models in a way that extracts the maximum possible information about the dynamics of the climate system?
The “handshake” question

- Data-model integration is a two-way process
- Proxy data can be used to constrain climate model simulations
- Climate models can provide dynamical interpretation of proxy data
- Everyone wins: we learn more about the dynamics of the climate system than when we employ the two approaches separately
ENSO over the past 8 ka
We know that ENSO has changed over the Holocene.

Tudhope et al. (2001), Science

Rodbell et al. (1999), Science

Moy et al. (2002), Nature
Orbital changes have been the dominant external signal...
... causing large seasonal changes in insolation
Climate model simulations

- The CSIRO Mk3L climate system model (Phipps et al., 2011, 2012)
  - Atmospheric general circulation model (5.6° × 3.2°, 18 levels)
  - Ocean general circulation model (2.8° × 1.6°, 21 levels)
  - Dynamic-thermodynamic sea ice model
  - Land surface scheme

- 10,000-year pre-industrial control simulation

- Three transient simulations of the past 8 ka:
  - Only the Earth’s orbital geometry is varied (Berger et al., 1978)
  - Atmospheric CO₂ concentration = 280 ppm
  - Solar constant = 1365 Wm⁻²
  - Each ensemble member is initialised from different years of the control simulation (i.e. a perturbed initial conditions ensemble)
Simulated amplitude of ENSO variability (500-year mean)
Trend in August surface air temperature (K ka$^{-1}$)
Trend in August MSLP (hPa ka$^{-1}$) and surface wind stress
Trend in August precip (mm ka\(^{-1}\)) and surface wind stress
With weaker trades, El Niño events develop more easily.
ENSO over the past 1100 years

Steven J. Phipps, ARC CoE for Climate System Science and Climate Change Research Centre, UNSW, Sydney, Australia

From Milankovitch to El Niño: Using proxies and models to understand the dynamics of the climate system
ENSO also changes on shorter timescales

Cobb et al. (2003), Nature
Natural/anthropogenic forcings over the past 1100 years

Equivalent CO₂ concentration

Total solar irradiance

Radiative forcing due to volcanoes

Steven J. Phipps, ARC CoE for Climate System Science and Climate Change Research Centre, UNSW, Sydney, Australia

From Milankovitch to El Niño: Using proxies and models to understand the dynamics of the climate system
Climate model simulations

- The CSIRO Mk3L climate system model (Phipps et al., 2011, 2012)
  - Atmospheric general circulation model ($5.6^\circ \times 3.2^\circ$, 18 levels)
  - Ocean general circulation model ($2.8^\circ \times 1.6^\circ$, 21 levels)
  - Dynamic-thermodynamic sea ice model
  - Land surface scheme

- 10,000-year pre-industrial control simulation

- Three transient simulations of the past 1500 years:
  - Orbital changes (Berger, 1978)
  - Anthropogenic greenhouse gases (MacFarling Meure et al., 2006)
  - Solar irradiance (Steinhilber et al., 2009)
  - Explosive volcanism (Gao et al., 2008)
  - Each ensemble member is initialised from different years of the control simulation (i.e. a perturbed initial conditions ensemble)
Reconstructed/simulated ENSO amplitude (30-year mean)

Steven J. Phipps, ARC CoE for Climate System Science and Climate Change Research Centre, UNSW, Sydney, Australia

From Milankovitch to El Niño: Using proxies and models to understand the dynamics of the climate system
## ENSO amplitude versus individual forcings

<table>
<thead>
<tr>
<th>Ensemble member</th>
<th>Greenhouse gases</th>
<th>Solar irradiance</th>
<th>Volcanic eruptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>+0.02</td>
<td>-0.24</td>
<td>0.00</td>
</tr>
<tr>
<td>2</td>
<td>+0.14</td>
<td>+0.27</td>
<td>+0.10</td>
</tr>
<tr>
<td>3</td>
<td><strong>+0.32</strong></td>
<td>-0.09</td>
<td>+0.03</td>
</tr>
<tr>
<td>Mean</td>
<td><strong>+0.30</strong></td>
<td>-0.04</td>
<td><strong>+0.09</strong></td>
</tr>
</tbody>
</table>
Conclusions
Conclusions

By integrating proxy data with climate modelling, we can use past climatic changes to study the dynamics of the climate system.

Orbital changes can explain the long-term upward trend in ENSO variability over the past 8 ka. Decreasing summer insolation results in a weakening of the Asian monsoon, reducing the stability of the tropical Pacific and making it easier for El Niño events to develop.

On shorter timescales, there is no evidence that natural or anthropogenic forcings influence the amplitude of ENSO variability. This supports the notion that ENSO is a system where variability arises from internal dynamics, independent of external forcing.

References